Algebraic Proofs of Nonlocality

Transparencies

1. EPR Argument (1935)
2. Einstein's Dilemma.
3. Proofs of the Bell Inequality – Two Controversies
4. Two Controversies contd.
5. Algebraic proofs of Nonlocality
6. History of algebraic proofs.
7. " " " contd
8. " — — — contd
9. GHZ proof
10. proof contd
11. No-Signalling
12. Proof that $A(\downarrow) = -A(\uparrow)$

13ad. assignment of values {v} in QM
13a Mermin's proof
13 Generalized Mermin proof
14 Simultaneous eigenstates for $T_1 \ldots T_N$
14a Irreducible contradiction for $N=3$
15 The infinite limit – "global" nonlocality?
16 Global Nonlocality
17. Odd $N \geq 3$, Even $N \geq 4$

PTO

18 Mermin Contradiction for arbitrary x

19 Mermin and the Connection with the Kochen-Specker Paradox

20 contd.

21 contd.

GHZ → non-locality

$$\phi = \left(|\uparrow\uparrow\uparrow\rangle - |\downarrow\downarrow\downarrow\rangle\right)\frac{1}{\sqrt{2}}.$$

$$T_1 = \sigma_x^1 \, \sigma_y^2 \, \sigma_y^3.$$

$\sigma_x \alpha = \beta$ $\quad$ $\sigma_y \alpha = i\beta$

$\sigma_x \beta = \alpha$ $\quad$ $\sigma_y \beta = -i\alpha$

$$R \equiv R_Y(180) = e^{i\sigma_y \cdot \pi/2.} = -i\sigma_y.$$

$R_Y(\pi)\alpha = \beta$

$R_Y(\pi)\beta = -\alpha$

thus $R(\downarrow) = -(\uparrow)$

$R(\uparrow) = (\downarrow)$

$$R_Y(\pi)^{-1} \sigma_y R_Y = \sigma_y$$

$$R_Y(\pi)^{-1} \sigma_x R_Y = -\sigma_x.$$

then $T_1 \phi = \frac{1}{\sqrt{2}}\left(|\downarrow\downarrow\downarrow\rangle + |\uparrow\uparrow\uparrow\rangle\right) = +\phi$

now consider $R_1 R_2 \phi = \frac{1}{\sqrt{2}}\left(|\downarrow\downarrow\uparrow\rangle - |\uparrow\uparrow\downarrow\rangle\right)$

and $T_1 (R_1 R_2 \phi) = \frac{1}{\sqrt{2}}\left(|\uparrow\uparrow\downarrow\rangle - |\downarrow\downarrow\uparrow\rangle\right)$

$$= -(R_1 R_2 \phi)$$

Note also $(R_1 R_2)^{-1} T (R_1 R_2) = -\sigma_x^1 \sigma_y^2 \sigma_y^3.$

So we can consider state still at ϕ but T gets flipped, so reversing sign of correlation

Classical limit of QM

(1) $\Delta p \Delta x \sim h \quad \Delta v \Delta x \sim h/m$

$m \to \infty$ — very slow dispersion
$(N \to \infty)$
But Schrodinger's cat shows $N = \infty$ can be superimposed — so quantal behaviour

(2) Garg-Mermin (1982) $S \to \infty$ limit of Bell
$S \to \infty$ is $N \to \infty$ in N-spin-½ chain —

(3) Hepp model of measurement.
∞ spin chain — states of superposition cannot be distinguished by local observables.

(4) Thermodynamic limit $N \to \infty$.
But specific heats, Debye theory e.g. shows quantal behaviour, but not involving large numbers of degrees of freedom. Each normal mode is quantized on its own.

if $\Delta x \simeq \hbar \quad \Delta p = \frac{\hbar}{d} \ll \bar{p}$
d ← spacing in lattice

where $\frac{\bar{p}^2}{2m} \sim kT$, so $\bar{p}\ \sqrt{2mkT}$

and classical behaviour holds for $\sqrt{2mkT} \gg \frac{\hbar}{d}$

$kT \gg \frac{\hbar}{\sqrt{2mkT}\,.\,d} = T_c$ = Debye temperature

(5) $\hbar \to 0$ in complex $\hbar$-plane
for Schrodinger Eq. exhibit
essential singularities
cf Bohm quantum potential $h \frac{\nabla \psi}{\psi}$.
does not always vanish as $h \to 0$
since for some solutions $\frac{\nabla \psi}{\psi} \sim \frac{1}{h}$.

(6) Cf. Geometric optics – abbe[?]
degeneration

(7) cf. SR. metric becomes singular
[illegible] when $c = \infty$.